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WESTERN ADEN PROTECTORATE

WATER PROBLEMS

Report by

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SUMMARY OF CONTENTS

The report deals with the prospects of developing water resources and extending cultivation in a limited number of localities distributed over some 52,000 square miles of territory where conditions appear favourable. The districts considered as likely to benefit most quickly and substantially as the result of an active development policy are a broad belt in the Aden hinterland to near Lahej, the delta of the river receiving the waters of the Wadis Bana and Hasan at Abyian and the Wadi Madin to a lesser extent.

On the highlands of Dhala and Mukeris where the produce of temperate climates can be grown not very much can be cheaply done to improve existing conditions due to the elaborate and praiseworthy measures taken to utilise all water that can be collected.

Attention is directed to the urgency of modifying the harsh conditions of land tenure imposed on present cultivators by landlords or rulers, and to the need of securing the removal or amelioration of other exactions which fall heavily upon hard working families fighting manfully against terrific odds. Figures are incorporated which show that highly profitable crops could be grown with reasonable ease in several localities where due to sociological causes cultivation is now strictly restricted.

THE WATER PROBLEMS OF THE WESTERN ADEN PROTECTORATE

INTRODUCTION

After receiving helpful advice from H.E. the Governor, Sir Bernard Reilly, Colonel Lake, Political Secretary, and other officers of the Aden Government, rather more than a month was spent in travel over selected parts of the Western Aden Protectorate where it was hoped something might be done to develop new water supplies and thereby improve the lot of the inhabitants. Throughout the investigations local Rulers, Administrative officials, and peasants were interviewed and their views ascertained when considering ways and means of providing better supplies of water for domestic, pastoral, and agricultural purposes, as well as a more rational development and distribution of existing surface and subsoil waters. Mr. B. J. Hartley, an agricultural authority, seconded from Tanganyika, accompanied all expeditions about the country and his advice on matters relating to soils and crops was most valuable whether considering the prospective value of undeveloped land or assessing the potentialities of land in cultivation.

As far back as 1917 a report was submitted by the writer on the ground water prospects of the Sheikh Othman region when tending advice to the Military Force at that time defending Aden, and although serious efforts to develop those resources were not made until many years later, drilling results have since demonstrated the views then expressed that large volumes of potable water could be drawn from the alluvial deposits of that district.

An examination was made of the following districts:-

1. Aden Settlement
2. Lahej and the flood plains of the Wadis Kabir and As Saghir
3. Wadi Madin
4. Abyian and the Wadis Bana and Hasan
5. The Dhala plateau
6. The Mukeris plateau

As might be expected soil conditions and water prospects varied widely due to differences in character of strata, topographical relief, rainfall, altitude, etc. Considerable expanses of country are covered with drift sand or sand dunes, and other parts are strewn with coarse rubble flushed by storm waters which in torrential fashion overwhelm strips of country during rains and render them almost valueless agriculturally. Scattered about the Protectorate are found in depressions or along water courses flats of fertile silt which when planted and watered grow healthy crops, and it is in such localities that farming or date culture is practised.

It was realised from the first that like various other parts of Arabia one had to deal with abnormal climatic conditions, and the absence of meteorological stations for observance of rainfall, temperature, humidity, etc., compelled reliance upon the rather treacherous memories of individuals who kept no records. Rainfall is exceedingly fickle and erratic in amount, incidence and distribution, and in consequence wadis with small drainage may suffer deluges or remain dry for a whole season, whereas those with large catchments are less liable to extreme fluctuations. We saw nothing to substantiate the oft-repeated assertion that the average annual rainfall is falling and water supplies diminishing. Doubtless pluvial periods have alternated with years of drought, but this is an experience suffered by all countries which owe their aridity to low rainfall and high temperatures and dry atmosphere.

Except in swampy undrained ground and land coming under tidal influences, no waters were met with, which would not support some crops, although some were high in saline content. A lack of humus in the soils appeared to be one of the misfortunes incidental to the climate and is a common feature in arid countries.

Ordinary rainfall on the scale experienced is quite inadequate to raise food crops and that is the reason why cultivation is confined to those parts where storm water can be developed to supply the deficiency of moisture.

The tribesmen are accustomed to employ temporary earthen dams for deflecting part of the flood waters of water courses into canals which are led to their farms, but their flimsy construction necessitates their annual reconstruction. Along some water courses such temporary bunds are found succeeding each other for many miles where there are alluvial flats to which the water can be conducted. By building permanent masonry dams at suitable spots with adequate spillway weirs to carry storm water and prepared outtakes, water could often be led to distant areas and basin irrigation practised. One single thorough wetting in the rainy season of a suitable silt will be enough to raise certain crops to maturity as is the case in Tokar and Kassala in the Sudan where high-grade cotton is grown on the dry deltas of the Baraka and Gash.

The native dams are made by throwing up earthen bunds reinforced by intertwining brushwood and saplings and introducing rush-work matting, and they are oriented to deflect flood waters into a prepared channel on one side of the wadi. Once topped they crumble and fall letting the storm water pass on to the next bund and canal downstream.

Little surface water, except during floods, escapes use where there is neighbouring land suitable for growing crops, but large volumes of water undoubtedly percolate into the ground in places where protected from evaporation losses it constitutes reserves which can often be profitably used in the dry season. This does not mean that much water is not wasted through inefficient distribution, for the effluent of springs and the dry-season flow of streams is frequently permitted to spread over a broad sandy bed lined with vegetation where it suffers high evaporation losses. Efflorescence of salts on the surface and the vigorous growth of figs, tamarisk and other trees affords some measure of the amount of water lost by capillary evaporation and respiration of plants. By confining the dry-season flow of wadis to channels or leading it away in troughs, much water could be saved for crops.

Both soil and water distribution depend upon local geological conditions which vary considerably in different parts of the Protectorate. The basement rocks consist of an igneous complex above which transgress a succession of sedimentary strata of Tertiary or Secondary age. The sedimentaries exposed are generally limestones of Eocene-Oligocene age sometimes underlain by Cretaceous sandstones or shales. The crystalline basal rocks of pre-Jurassic age are generally basic in character often pierced by secondary intrusions of more resistant dyke material, but in some parts granite rocks predominate. In some localities crystalline gneisses and schists betray the existence of an old metamorphic series. Near the coast volcanoes of post Miocene age have led to the formation of great cinder heaps and lava flows encircling some centre of activity, and elsewhere undisturbed sheets of basaltic lava have spread in fan fashion seawards covering sedimentary rocks of all ages over which they flowed.

Topography is largely determined by the extent to which the rocks have been disturbed, distorted or fractured after sedimentation, and the amount of differential weathering where two or more types came in contact. The associated soils are sandy, calcareous, or argillaceous

(clayey) according to the character of the prevailing rocks in the catchments from which rainwater drains. Whilst the beds of some water courses consist of coarse siliceous sands others are composed of calcareous muds and pebbles or tough clay silts in which pebbles of hard rock are embedded. Limestones, shales, sandstones, igneous and volcanic rocks of basic or acid type in varying proportions influence the character of soil mechanically and chemically as well as their fertility. The salinity and hardness of both surface and subsoil waters is also dependent upon the same conditions, and excess of lime or clay in some waters accounts for the low permeability of coarse alluvial deposits which fill many depressions and valleys and would otherwise be prolific producers of water.

Perennial irrigation by well water is practised in all parts of the Protectorate where the water table lies within a practicable depth from the surface. The economic depth limit depends upon the type of soil, quality of the water, altitude of region, condition of land tenure and accessibility to markets. In some districts 20 to 30 ft. is regarded as the extreme depth, but in others crop irrigation is regularly practised with water at 60 to 70 ft. although this latter figure may represent the limit admissible under general conditions of farming as now followed. As a general rule irrigation by well-water follows flood watering and in fact completes a process started by rain or floods or saves crops that received an inadequate flood. Mr. Hartley is firmly convinced that by the introduction of improved seeds, a wider range of products, better rotation arrangements and more scientific fertilising of the soil, much larger and more valuable crops could be raised, and this aspect might modify present views regarding the economic depth of water.

Travelling about the country, one found little departure from a conventional form of farming land with primitive implements and animal labour. Existing methods admit of no criticism as the tools are all made locally and are easily repaired or replaced. The fields were generally neatly levelled, ploughed, weeded and cleared of stones, and prepared furrows were made for leading the water to basins into which the fields are divided for convenience of watering. Provision is made for all run-off water that can be conveniently captured to be conducted in channels which branch at intervals to the various gardens sharing in the supply, and even runnels and stones are arranged along flattish rock surfaces to deflect surface drainage to some useful point.

In some regions not a patch of workable soil has been neglected, and elaborate and praiseworthy terracing has been carried out in order to conserve soil, check erosion and ensure effective watering and drainage. In other places great expanses of useful country were left untouched where there were no obvious reasons for neglect as soil fertility was satisfactory and water was plentiful. This condition appears to have resulted from sociological causes which appear to have a considerable bearing on the state of agriculture in some of the more lawless regions. Onerous conditions of land tenure, unjust exactions, filching and robbery, insecurity through strife and flood feuds, usurious money-lending and such-like causes, singly or jointly, frequently tend to discourage peasant working. Although the conditions vary much in different areas, rentals and crop participations were far in excess of what could be regarded as reasonable. Sometimes confusing conditions were imposed on farmers who tilled, planted and watered the soil on which date-palms of other ownership were grown by paying the landowner a share of the ground crops and withholding some proportion of the dates for services rendered.

In addition to the above deductions the cultivator is usually mulcted in other charges on the road at tribal boundaries or custom barriers so that profits are usually reduced to a bare livelihood such

as discouraged all but the most enterprising and determined. Cases which came to our notice are given in the body of the report, and Mr. Hartley is satisfied that no crops will stand such unjust and iniquitous exactions. Before some of the promising areas are taken in hand for more orderly development, it would appear necessary to secure some equitable adjustment of rentals or crop participations. Obviously it can be no policy of the Government to subsidize agriculturists for the benefit of the rich landowner, and by some means possession or control of land should be obtained where experiments can be conducted under supervision on land rented to willing workers on reasonable and equitable terms more in line with those customary in other countries.

Water rights of ancient origin cause much heart-burning, and sanguinary conflicts due to attempted or actual deflection of supplies upon which some tribe depends for its existence, and an almost fanatical respect for complicated distribution agreements is likely to render difficult fair or scientific adjustments and re-arrangements. The prior claims of Rulers with despotic powers may prove exceedingly difficult to satisfy if efforts are made to alter prevailing customs. In some places a kind of water-board apparently exists to regulate the distribution of flood or spring waters, but precisely how it functions and how just its decisions it was impossible to ascertain. Obviously some such scheme under disinterested guidance would be of great benefit to the community and the authorities although not easy to inaugurate or regularise if in existence.

Extreme poverty was the excuse generally advanced for the neglect of several areas seemingly capable of agricultural development. Nothing was noticed to substantiate the charge of indolence on the part of the people, but it may be that caste and customs place hindrances on some classes.

It was considered inadvisable to submit schemes involving large scale experimentation with subsoil water raised at central pump stations. Farming in Arabia is essentially a peasant industry, and as a rule one well will irrigate between one and three acres according to its yield, capacity and depth to water.

The people are not yet mechanically minded and machinery would require skilled supervision from abroad. Most of the plant we saw in the Protectorate was sadly neglected and in a poor state of repair, and machines should be introduced slowly. Modern windmills require a minimum of knowledge and attention and have proved very suitable in many African colonies. Another factor influencing such a decision is the restricted yield of wells in many areas due to the nature of the strata, and frequently an extraction rate of from 500 to 2,000 gals. per hour reduces the water level considerably or dries up the well. Reference is made in the report to districts where large withdrawals of water can be effected without any detrimental fall of level or endangering of permanence, and there are named places where drilling to depths beyond the reach of shafts are likely to result in much more prolific sources being tapped.

Much might be done to help the well diggers by giving them better tools to deal with hard rocks, and a little instruction in shaft sinking would certainly repay the temporary engagement of a miner from home. The Bedouin pastoralist seems to deserve some consideration for his nomadic habit in search of grazing and water, for his herds must cause him incessant anxiety at certain periods of the year. The construction of permanent wells at strategic points would be highly appreciated by those in charge of herds and flocks which are kept on the move by the search for water, pasturage or markets.

Where so much is needed it is difficult to know where to start, and there is always the uncertainty as to the attitude of the populace. The introduction of machinery should be slow for unless under skilled direction it may fail in its object. Oil-engine driven pumps are in regular use and the extended use of motor-cars is creating a class of mechanically-minded men. Windmills can certainly be introduced with safety as they need so little supervision when once properly erected. At least one mechanical percussion drill should be purchased to drill wells in the Aden Settlement, at Abyian, Hiswa district, and elsewhere where water may be anticipated.

ADEN SETTLEMENT

(Area 75 square miles)

The numerous wells at Sheikh Othman give very positive evidence of the ground water potentialities within the Settlement, but too little drilling and pumping has yet been done to prove the extent of the water-bearing formations and their capacity to withstand heavy withdrawals. In the financial year ending March 1937 the water pumped from Sheikh Othman wells is given as 203,000,000 gals. of which 97,000,000 was for gardens, free services, and shipping. Along the strip of coastline between the delta of Wadi As Saghir and the Wadi Kabir at Hiswa an enormous quantity of subsoil water having its origin in the hills and wadis to the north-west flows seawards, but the bulk may follow more or less coarse strips of alluvial representing ancient major channels. However, the conditions do not suggest a very selective course for ground water flows, as widely-distributed wells yield water of varied but potable quality unless sunk too near the sea where the influences of tides and capillary evaporation come into play. The ground water is fed by a succession of important wadis, all of which are lost on the plains as their discharges sink into the ground and percolate into the porous strata. A tidal movement of about 12 ft. in the Gulf of Aden must operate in determining the water table, and a number of tests can prove just what is the effect and how far it extends from the shore line. There are sound reasons for believing that abundant supplies of low mineralized water could be developed within the Settlement and just beyond at depths up to a few hundred feet with static levels between 15 and 40 ft. from the surface. Should permeable gravels be struck at depths exceeding 20 to 50 ft. beyond the belt where there is a diffusion of sea and land water, very large supplies could be safely anticipated.

Near the sea low-lying lands are very saline and thickly encrusted with salts due to the water table being sufficiently near the surface for capillary evaporation to proceed, but this does not preclude the possible occurrence of less saline water at depth. Around Hiswa dom palms flourish on the salty earth where the water table is shallow, and just beyond at higher levels the whole country is parcelled out into basins for irrigation by flood water should the floods reach so far. With Sheikh Nassin a tour of the district was made and we witnessed preparations in progress for deflecting the anticipated flood water from the wadi bed into canals. The depth of a number of wells was measured where water of potable quality was being drawn from depths between 40 and 60 ft. Drilling is certainly justified in this area if the people can be induced to take up land and water gardens from wells.

Within range of sea breezes profitable use could almost certainly be made of windmills to pump water such as is practised by the salt works and to some extent by owners of gardens in Sheikh Othman. With water within 20 ft. of the surface and stiff regular winds, a single mill might deal with about an acre of cultivation. In the appendix some figures of cost are given. The public garden at Sheikh Othman gives a fair idea as to the potentialities of the district with an ample supply of water, and an experimental plot would well repay any cost involved in

its upkeep. We would suggest the sinking of several boreholes to the main aquifers at a point chosen for a farm, and that one or more be fitted with pumps and engines, and two others with windmills for demonstration purposes. These should not be located nearer than half a mile to the Sheikh Othman wells in order to avoid any possible interference with the waters of that region. The orientation of water channels and gravel deposits in a general north-west - south-east direction removes any possibility of interference by bores sunk east or west of Sheikh Othman.

LAHEJ (ABDALI) DISTRICT

Some days were spent in and around Lahej in investigating the problems related to the irrigation of an important belt of cultivation watered by the Wadi Kabir which supports a perennial flow of water. Before starting and on the completion of the study, interviews with H.H. The Sultan of Lahej led to an expression of his views and wishes and he was most anxious to know whether artesian (flowing) water could be obtained on ground substantially higher than the wadi bed which is usually far below the densely-cultivated areas. Apart from this, His Highness's main wish was to improve the system of irrigation, if that were possible, as all experiments with pumped water from wells had been economic failures due to one cause or another. In all our journeys about the district we were accompanied by His Highness's brother, the Sultan Ahmed, who proved to be a delightful companion and is a keen farmer amply supplied with modern agricultural literature and continually experimenting with new types of plants obtained from other tropical and sub-tropical countries.

The cultivated area is watered by a series of canals led off from the main wadi bed at numerous points along its course from below Al Anad at an altitude of 1,000 ft. to a point near Hiswa on the coast. This procedure is rendered possible by the steep slope of the wadi bed, the take-off canals from which follow a more gentle gradient laterally until they reach strips of silt with very moderate slopes. During the flood season much silt is carried by the water, and the canals run over country which in course of time has been artificially raised far above the normal land level. The ground is divided into more or less rectangular blocks by mounds for basin irrigation, and in these such crops as millet, maize, beans, lucerne, vegetables and melons are grown. At a point near Makashaba the Wadi Saghir branches south-east and conducts some of the water from the main river to an eastern sector of land unspoiled by drift sand or erosion. During spates, when the river runs high, the water is deflected by earthen embankments into the few main canals, but when carrying quantities in excess of that needed for the land, the water flows onwards to the delta and reaches the sea by two branches, one near Hiswa and the other some twelve miles from Aden on the Eastern coast. To these annual floods must be attributed the prolific yields of wells at Sheikh Othman where the Aden water works are now situated and producing about 400,000 gals. a day for Crater and Steamer Point.

The present-day water courses of Kabir and As Saghir doubtless represent two of the many more ancient valleys which drained the hill country but are now concealed by surface drift, and exploratory drilling would doubtless result in the discovery of many deep channels with sand and gravel still carrying large volumes of water seawards.

One way or another some 20,000 to 30,000 acres of land in the Lahej district is alleged to come under cultivation by irrigation, but the area naturally depends upon the size and frequency of the floods, which in turn depend upon the amount and intensity of up-country rains. At Lahej itself the normal dry-season flow of water was said to be sufficient to

irrigate 25 acres daily, whilst further downstream the area fell to 10 acres per day, but in any case around 5,000 acres of land come under perennial cultivation at ordinary times, although it may in some years fall to less than 1,000 acres. The figures would indicate, assuming a 3 ft. watering per crop, a water volume of about 100,000,000 M^3 a year used in Lahej district, disregarding floods.

No orderly distribution of water is arranged, and much might be done under skilled supervision to direct the waters about the country in a better way, and especially wasteful of water and labour appeared the irrigation of lands on the steep slopes of the Wadi bed where high bunds had to be built on the banks to form basins where water could spread evenly. On mentioning this aspect to the Sultan Ahmed, he said that this was due to respect for ancient water rights carried by the land and that they could not be altered. Obviously water could be much more economically used by leading the canals to flat areas of which we saw many more distant from the sloping wadi sides. Except in very lean years some part of the flood of the Kabir and As Saghir channels reaches the Settlement at or near Bir Ahmad and Fiyush where there is cultivation when flood conditions allow.

Water rights are so strenuously and jealously guarded by those with power to enforce respect that there seems little chance of modifying existing conditions, and a realization of this fact led to attention being given to the prospects of developing subsoil waters in areas where the wadi water was inadequate or unobtainable. Sufficient wells were found about and around the cultivation to give a fairly safe idea of the depth of the water-table and the yield of wells, but we found few who would commit themselves to a statement that subsoil water would repay its abstraction and use. As an example may be mentioned one peasant cultivator growing about half an acre of ochroes and some millet and other crops on about two acres. His well was 60 ft. deep and cost him Rs. 50, and he used two camels and two oxen for drawing water, watering the basins once every six days. The crop was good, the plants healthy, and he said he was just able to pay his way and support his family when paying a rental of Rs. 40 per acre year. The plants cropped in $1\frac{1}{2}$ to 2 months after planting and yielded for 5 to 6 months, and he packed ten baskets of ochroes a day for the Aden market.

Here then was definite proof of what could be done under the very adverse conditions of iniquitous rental and deep water from an unlined well which required replacement each year, situated some 15 miles from the Aden market. With water in a permanent lined well at 30 ft. instead of 60 ft. and a rental of a few shillings an acre instead of Rs. 40 (£3), the conditions would have been quite different and would have encouraged widespread exploitation by peasants.

Sultan Ahmed stated in conversation that he once obtained Rs. 1,600 for one acre of melons when water was scarce and prices were high in Aden.

Excursions were made along the Kabir and As Saghir channels both northwards into the hills and southwards toward the sea, and wherever we found wells there appeared to be water of acceptable if variable quality in quantities and at depths lying between 40 ft. and 110 ft. The deepest wells were found around Waht where the water-table suddenly sinks even close to the wadi bed which is here clearly defined by a deep channel. In most cases gravels were reported in the wells so that good yields could be reasonably anticipated once they were struck some distance below the most depressed dry-season water table. Certain wells to which we were taken or about which we were given information had been pumped heavily without exhaustion, especially that sunk near Lahej many years ago for the projected water-supply of Aden.

Beyond the range of canal water, sites could certainly be selected where water in abundance could be obtained at depths of 40 to 50 ft. on land suitable for cultivation and removed from drift sand. The economics of cultivation by pumped water could surely be decided by a trial installation under skilled guidance and observation. We are disposed to attribute past failures to the use of old inefficient and unsuitable machinery, liable to frequent stoppages through lack of attention and perhaps to wasteful distribution of water. Some figures of water costs based on fuels of various kinds are appended, and knowing just what amount of water is needed for different crops, it should be an easy matter to calculate what revenue is possible under usual market conditions, provided no unfair dues are exacted from the cultivators and pilfering is stopped.

A trip westwards from near to Wadi Abrain, one of the many water courses which stretch from the hills in the north-west and drain into the As Saghir system, indicated the presence of water in that part of the country. A group of wadis having poorly-defined channels are distinguished mainly by belts of vegetation, but they showed signs of flood waters and although wells are few and far between the conditions appear favourable for developing water by wells of moderate depth.

The prospects of striking artesian flowing water in the Lahej district are regarded as extremely unpromising. The rocks outcropping in the hills to the north beyond Al Anad are somewhat disturbed trap (volcanic) rocks lying upon a granitic basement seen in outcrop in the Wadi Kabir. The traps are well bedded but both traps and granites are pierced by volcanic dykes which destroy their continuity and cut them into sections. The traps are decomposed and cracked and undoubtedly absorb some water, but the low local rainfall does not encourage much hope of tapping useful supplies under pressure. The alluvial deposits which stretch southwards from the hills to the sea would appear to be too permeable to admit of a banking up of water pressure. Most waters in the alluvial deposits are under a pressure head which ensures a rise of water to about the average water table of the district when struck, but the wells at Sheikh Othman have proved that the series is too porous as a whole to cause natural flows except perhaps in small quantities from isolated lenticles inheriting flood level pressures that would soon drop.

To the north the Saghir bed enters a gorge flanked by crystalline rocks, and it would be possible to impound water by damming the bed at some selected narrow spot. As a reservoir such a scheme is not likely to be successful, as it would silt up and soon have little capacity, but as a barrage to raise the level, so that water could be carried to higher ground, it might prove quite useful.

WADI M'ADIN

The journey to Wadi M'adin was via Sheikh Othman and Waht by a track westwards over broad stretches of bare, drift sand with only occasional breaks of hard desert. Not until Am Rija was approached did we meet anything in the nature of a water course, but here a very pronounced depression skirted by river terraces and lined with thorns, tamarisks and other scrub was reached at some 400 m. above sea-level, the catchment lying in the hills to the north-west. Here water was obtained from a well 78 ft. and stated to be of good drinking quality, but whether the water was obtained from alluvial deposits or rock, we were unable to ascertain. The Wadi Am Rija is composed mainly of granitic pebbles and quartz sands, and just beyond granitic rocks outcrop at the surface and the country is thickly studded with Euphorbia and thorns. From this point pleasant scrub country was entered and a series of wadis was passed which gave evidence of carrying much water in the rains. Up-stream of Am Rija there were some flats of silt on which millet was grown after the floods and a few old date palms had survived the vicissitudes of climate.

The Wadi M'adin was entered at an elevation of 610 m. and subsequently followed for nine miles to 850 m. where we came to the frontier fort of To El Baha, where a guard is stationed. Nearly the whole way the wadi was lined with flats of silt to which water was conducted in prepared channels during the flood season by leads from the bed. Off-takes were noticed at frequent intervals, the fall of 27 m. per mile giving latitude for any number of outflows. Wells were extremely scarce and the people went long distances for their water. One, Bir Al Qatabya, near where the wadi was entered, measured 54 ft. to water and was said to give enough for the domestic needs of nearby villages and passing cattle. Residents of the villages at Samsitsa and Amgrijeb stressed their poverty as excuse for absence of wells, but the clean condition of their fields rather belied the suggestion of indolence which is often alleged to be the cause of their impoverished state.

Just beyond the latter village the western bank was thickly lined with healthy flowering date palms, and a little further up-stream fields of maize came into sight. The cause of this was soon made manifest when rounding a bend we suddenly came upon running water coursing over a sandy and grassy bed where numbers of cattle and goats were contentedly grazing and watering. For the distance of about a mile there was flowing water before it disappeared, and the volume was quite considerable and judged to be of the order of 50,000 gals. per hour. This water is led by canals to the palm groves and cultivation along the banks on some agreed basis of distribution. At the Fort there is a well in the wadi bed with water at 33 ft., and this is sunk on the very edge of an outcrop of granitic rocks intermingled with gneisses. Only a little further up-stream the wadi enters a gorge and reaches Yemen territory, and the mountains rise to a height of some 6,000 to 7,000 ft. all igneous in character as their form of weathering shows. The wadi runs the whole way in crystalline rocks of many kinds varying from coarse granitic masses like pegmatites to fine-grained glistening traps and gneisses with foliation not highly developed.

H.E. the Governor expressed a particular interest in this wadi where perennial cultivation could be greatly extended if water could be made available the whole year. Although the local tribes were regarded as particularly truculent and untrustworthy, there is a feeling that they are not so bad as pictured and that given opportunities of expending their energies on pacific duties they might become reconciled to a peaceful life. Without doubt better use could be made of the "spring" water which is permitted to wander about a broad sandy bed for nearly a mile, suffering heavy evaporation losses. If conducted in masonry conduits on each side of the wadi, or in pipes directly into canals, much water would be saved, sluices or valves providing for discharges at any points where water is required for animals or domestic purposes. Below the springs and take-offs it is probable that wells sunk into the wadi bed would give large and sustained supplies of water which now percolates down-stream unseen and unused in the wadi alluvials. Time did not admit of a study of the circumstances causing the "springs" but they would appear to be no more than the forcing to the surface by a barrier of water which higher up the valley runs underground. This may not be a true explanation, for the water may issue from rock fissures connected with some line of disturbance, but if the first interpretation is correct, prolific wells might be sunk up-stream to tap the underground flow. The Fort well is no criterion as it was sunk on the side of the wadi in rock and not in the alluvium.

The sinking of test shafts above and below the springs near the middle of the wadi bed is recommended and, if successful, the installation of some kind of pump using animal or wind power might be entertained to lift the water into prepared tanks for feeding new canals. Shafts or borings in the igneous rocks are likely to give moderate and consistent supplies, but the wadi alluvial deposits are most promising although it will be necessary to explore the bed in order to find the deepest spot in which the flow of water may be confined.

ABYIAN DISTRICT: FADHLI AND LOWER YAFA

Some 35 miles north-east of Aden two important watercourses carry the drainage and during rains the run-off of barren rocky hill country to the north, and the water is used to irrigate a strip of lowland where the surface contours and the soil conditions are favourable. The Wadi Bana drains high country to the north-west and the Wadi Hasan mountainous territory to the north and north-east. Between them some 50,000 to 60,000 acres of land are shown on the maps as coming under flood cultivation, and a considerable acreage is under perennial watering by canals and wells. Sheikh Abu Haidara very kindly extended hospitality at Al Kud and arranged guides to take us about, but desperate feuds over water rights are a great hindrance to orderly development of land presenting perhaps the best prospects of profitable development in the Protectorate excepting only Lahej. Near the coast the wadi beds are broad, flat, sandy strips, over which cars can only travel with difficulty, but some miles up-country they narrow, the beds harden and become strewn with gravel and boulders of igneous rocks. Cultivation is restricted to areas free from drift sand where the topography admits of canals being given a satisfactory alignment on fertile silts.

In the vicinity of Al Kud, irrigation by well-water is practised quite extensively, due no doubt to the occurrence of plentiful supplies of water at a depth of about 20 ft. Proceeding northwards, the depth to water increases but it generally lies within 30 to 50 ft. from the surface according to the land elevation and the proximity of canals. A journey was made up-country to Al Husn Bani Attga where we were received in friendly manner by the Sultan, from whom something was heard of the water scandals. Near the town a canal was carrying a pleasing flow of water to cultivation of the Lower Yafa tribe along the Bana branch. From the roof of the Sultan's house a good view of the valley system was obtained up to Narriana (Al Masana on map) where the Wadi Bana makes a sharp sweep to the west and the Nazia canal was constructed to conduct the flow of water into the Hasan belt of cultivation, the water rights having been purchased by the Fadli's many (80) years ago. The uncertainty occasioned by tribal fights over the water at the bund, which is alternately opened and closed by the one who gains temporary ascendence, is a serious hindrance to organized developments, and this warfare will only cease when order is enforced.

No irrigation by well-water was observed up-country, but the conditions appear favourable for the development of ground water at selected spots removed from the many hills of disturbed and shattered trap rocks which rise from the plain. Only pebbles of trap rocks were found in the wadis and little quartz was noticed, although some of the exposed traps are so thickly-veined with white quartz as to give the hill-sides a white appearance.

Near the coast, wells appear to draw their water from rather fine, even-graded, loose, micaceous sands, which do not yield freely and always give trouble through caving and in-running. The difficulty of cavitation has been partly overcome by an ingenious screening of the well sides with woven tamarisk twigs encircling a plaited brushwood lining. By this means the cultivators are able to extract between 700 and 1,000 gals. per hour without much delay for allowing a recharge of the wells after a lowering of level.

Two opportunities occurred for viewing the Abyian delta from the air, once when flying from Mukalla to Aden and again when taking plane to Mukeris, and it was indeed an impressive sight to see such a large expanse of green bordered by arid, desert wastes. Without doubt peace would create a sense of security and attract settlers, and the recent appointment of a resident political officer, Mr. Shepherd, is likely to encourage a return of the more peaceful element driven by feuds and strife

to leave the district. However, there are other difficulties to surmount, for it was learned from cultivators that grossly exorbitant rentals were demanded as well as other exactions which need revision before peasants can be expected to settle contentedly on the land. From chats with families engaged in watering their fields from wells near Al Kud it was ascertained that a rental of from Rs. 80 to Rs. 100 was paid for something of the order of an acre of ground irrigated by a well which cost Rs. 100 to make. The produce grown comprised cabbages, peppers, tomatoes, ochroes, beans, herbs, and some oil seeds, dura and lucerne for animal food, and they had six bullocks costing Rs. 60 each to work day and night at the well. The farmer had to buy additional fodder for his animals, ropes and skin buckets for the well, and baskets for the produce he despatched to market. He had also to pay pickers and men at the well. He sent to market one camel-load of produce daily for three months paying 12 an. tax per load to the Sultan and Rs. 2 for hire of camel to Aden. The net result was a surplus of from Rs. 1 to Rs. 2 per load over the period when crops were bearing.

Mr. Hartley maintains that such exactions are prohibitive and he knows of no garden or farm products that would justify such charges. Before settlers can be expected to take up land some substantial amelioration of rentals and taxes seems necessary. H.H. The Sultan of Lahej stated in conversation that he had purchased a large area in Abyian. From timing with a watch it was estimated that the output of a two-bullock well was about 700 gals. per hour, and we were told that most wells had to be re-constructed each year after the flood.

Given a square deal, the Abyian delta opens up for peasants an important field for settlement, as the ground is fertile and flat and the water plentiful, and it lies within easy reach of Aden where a good market exists for produce. We believe windmills could be used with advantage in these parts near the sea where the water is shallow and the sea breezes well sustained.

Within the limits of present-day irrigation by water wells the fine-grained unconsolidated sands are liable to worry the peasant as they require constant clearing and do not yield very freely. By boring to greater depth there are good prospects of striking coarser sediments which would yield more freely and give no trouble, so that if a rig is purchased some trial wells should be sunk in the district. Under skilled advice much larger producers could be constructed on the gravel-fill principle, but these would prove far more costly and are scarcely to be recommended except as an experiment by the Government if and when the land becomes the object of intensive cultivation.

Before leaving Abyian a trip was made eastwards, and after crossing the Bana sandy bed belts of tamarisk forest were crossed for some distance beyond the Hasan dry course. Although swept by sand drifts on the route taken there are likely to be many patches of ground which could be watered by wells after the flood crops have been reaped. At Bir Alt, water is met with at 42 ft.; near Asala there was water at 36 ft. and although the quality is not always good, there appears to be water about the plains at depths within a workable limit. Except for a few herdsmen and travellers we saw few people and passed no villages.

DHALA PLATEAU

Situated on a plateau 5,000 ft. above sea-level and half encircled by mountains which rise another 1,000 to 2,000 ft., Dhala is the administrative centre of an Emir who rules Amiri tribes in country bordering Yemen territory. The plateau is approached from Lahej by a road which follows a succession of wadi beds in and out of which the road emerges at intervals to traverse intervening strips of broken country often covered with drift sand or supporting scattered thorn-bushes.

Along the wadi beds there is frequently a fringe of vegetation, and where water occurs at a moderate depth shady figs or Elb trees thrive. Where the wadis broaden, strips of alluvial silt have been terraced with stone walls or mud banks and fashioned into basins where storm-water is led by canals when rains occur. Occasional wells supply nomadic herdsmen with their requirements and the inhabitants of villages with their domestic wants of water, and at times a restricted amount of irrigation is performed by well-waters. Dura appears to be the main crop grown by both systems, although maize and hardy vegetables are sometimes cultivated.

The whole country traversed is built up of interbedded trap rocks, often thrown to steep angles with no consistent regional dips and frequently pierced by hard prominent dark dykes standing at a nearly vertical angle. Only basic rocks were seen on this journey, and the basaltic type weathers readily into a dusty silt or peppery gravel which fills the wadi beds. On eminences along the wadi sides are perched occasional clusters of mud or stone dwellings built to repel attacks and to support defence.

Near Dhala and in the system of valleys between the ranges of hills every patch of soil has been carefully levelled, cleared of rubble and cultivated even on the slopes of alluvial fans which carry the run-off from the mountains. Only by years of patient toil could the accumulations of silt washed from the mountains have been collected and formed into rectangular plots with earth surrounds where surface flow of water can be deflected and ponded to give the soil its necessary watering. On the steeper gradients the fields have been built up into terraces with stone walls, some having a drop of many feet on the down slope side. By a clever disposition of canals and spillways, flood waters are conducted from basin to basin or shared in such a way by branches that all the cultivable land gets a good soaking when the quantity admits. Scarcely a single helpful suggestion could be made to improve matters, and one could only admire the skill and energy employed in making the fullest possible use of all available soil and water. On the rocky ground separating the strips of cultivation, channels have been cut or guiding walls had been made to direct any surface-run-off of rainwater to the fields, so that little or none is ever lost except that which percolates underground and that which evaporates.

During the course of several days in the company of the Emir, visits were paid to many wells, springs and surface showings of water where views were solicited regarding the feasibility of developing water to greater advantage. In every case no other advice could be tendered than to develop to a greater extent the ground water which undoubtedly exists at many spots, and which at times is brought to or near the surface by subsoil obstructions. Near Dhala well-water is employed for irrigating gardens and fields of Yat,* and there appears no obvious reason why the system should not be extended. The area near Dhala is not very suitable for accumulations of subsoil water as the catchment is small, the rainfall low, and the rocks not very absorbent. Wells vary from 30 to 50 ft. in depth, and as the inflow is slow the yield per day is not very great. In some the water is derived from coarse alluvial deposits below the silts and just above the trap rocks, and in others water is obtained by slow infiltration from fissures in this basement rock.

Well sites are apparently selected by men (diviners) who claim to be able to locate water, but judging by the very unfavourable positions of many and their small yield, the talents of these exponents seem to have been over-rated. Others were obviously well-placed and would be likely to yield better than the majority. Attempts were made to interview the professional well-diggers who have nothing to do with the selection of sites, but for some not very clear reason we were only able to see one old man who had only sunk two wells into the rock. He maintained that unless water was found in a coarse detritus above the rock, it oozed from fissures and cracks in the rock in the manner that was anticipated.

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* A species of narcotic herb largely used by the people for chewing.

The wells measured had depths of from 30 to 60 ft. and some needed frequent cleaning out. Those in silt or alluvial were neatly lined with a circular surround of rubble or stonework which ensured their permanence. Their cost was not procurable as they are made by day-work, and in rock progress was described as slow and expensive, as explosives had to be used.

The Emir Haidara conducted us to the deep wadi which drains the high mountainous area to the west of Dhala and here we found that, owing to a narrow divide, water could be switched either north-eastwards into the main valley or south-westwards over terraced ground to the head of a precipitous cliff from the base of which the Wadi Dareiga runs to distant plains. At the top of the drop the valley contracts to a narrow gorge crossed at right angles by a hard dyke which holds up all subsoil flow. Ground-water moving in that direction is thereby forced to the surface, and a stream issues as a spring and cascades over rocks before plunging into the ravine below and following a steep watercourse. Near the waterfall have been deposited considerable accumulations of highly-cellular calcareous tufa or travertine caused by precipitation of lime from the hard waters on exposure to the atmosphere and aeration after its travel underground. The heavy lime content of these upland waters which constitute the run-off of igneous rocks is due to the considerable amount of calcium carbonate formed as a result of the decomposition of lime-containing minerals in the rocks. This tufa is quarried by the people and burnt to prepare whitewash for their dwellings. Neither the flow nor the fall could be measured in the time available; but if the volume is large and sustained, it might be considered worth while to give consideration to the installation of a water-turbine for cheaply generating electricity for the Palace, Rest House or a hotel if built here. An almost sheer drop of several hundred feet was indicated.

A journey was made up the large wadi draining Jebel Jihaf and followed until flowing water was found at a considerable altitude. The visible supply was small but it showed that the wadi bed was fed by springs issuing from the disturbed and dyke-intersected igneous rocks. At one spot masses of calcareous tufas were observed on the mountain-side, showing that lime-carrying water had descended here in the past. No water of economic importance was however met with.

Another excursion with the Emir and his bodyguard was to Sanah and Bajaha near Lakamat Dowki, and at Bajaha water was found at the surface. A swampy strip of silty ground fixes the area where water lies within the range of capillarity, and several thick forests of tall tamarisk roughly define the limits of shallow water in this part of the country, particularly where wadi mouths reach the plain. Wells were met with at intervals, but none was used for irrigation purposes and many gave only small yields. Other wells could certainly be sunk and without doubt much ground-water could be made available by sinking wells or boring deeply into the alluvial deposits or into the decomposed surface of the rock. All the villagers seemed desperately poor, and at Lakmat we found their few animals dying from rinderpest. Proximity to the Yemen border doubtless causes a feeling of insecurity which discourages much outlay on works which might arouse the envy of unfriendly neighbours.

MUKERIS PLATEAU

A short visit was made to Mukeris in February to view the rather unusual conditions which prevail in that delightful upland country situated at an altitude of about 7,000 ft. The plateau was reached by a flight from Aden in three R.A.F. machines which rose to about 9,000 ft. before crossing the Great Scarp separating a rugged foothill country from the gently undulating plains above. When landing and taking off, a fine panoramic view of the country was obtained in brilliant sunshine after leaving the cloud belts filling the many depressions and valleys between

rocky ridges. Proceeding from the landing-ground, one walked for miles through strips of ploughed soil accurately levelled and cut into suitable sectors by earthen banks for stage watering. Stone terraces crossed every valley at short intervals, to preserve soil and to enable the enclosed earth to be levelled off for irrigation; and as the valleys contracted so did the fields, until towards their upper ends cultivation was confined to a width of a few yards.

Where uncovered by silt the strata consisted of a confused mass of granitic rocks with micaceous gneisses shot through in all directions by dark-coloured sub-basic dykes which at times reached almost a network. The granites and gneisses decomposed readily into a sandy detritus which, mingling with the more clayey residues of the basic rocks, produced a light and fertile soil upon which wheat and millet thrived. From the air some of the basalt type rocks looked like craters, but no actual centre of activity was seen on the ground. No sedimentary rocks were found, but some calcareous decomposition material was found clinging to the face of the crystalline complex, and a few terraces of cemented debris were noticed representing ancient and higher levels of the valley floors.

Along the major valleys fields of sprouting green wheat were being irrigated by water from numerous wells worked by bullocks or camels, and this was said to be a second crop which would be harvested in June. Occasional flowers, fields of Alfalfa, and some few trees created a pleasing scene, and the enjoyment was enhanced by the hearty, if embarrassing, welcome extended to us by the local authorities and farmers.

At the altitude the temperate yet sunny climate favoured the growth of many sub-tropical plants, just as in parts of Kenya and Tanganyika, provided water is made available, so there was a natural anxiety to develop as much water as possible in order to support crops the whole year.

With the geology so clearly defined, a diagnosis of the hydrological conditions was a simple matter and such information as we were able to collect by patient cross-examination confirmed the impressions formed. Within a rather undefined range of the capital town there were, it was said, about fifty wells, but no more accurate figures could be obtained.

Although the Ede Festival was in progress and the people disinclined to curtail their pleasures, we succeeded in finding a man who said he had sunk twenty wells in the district to depths between 40 and 70 ft. in from one to five months each according to depth, diameter, and hardness of rock. Most had yielded some water and some were very free producers and could not be exhausted by the usual process of abstraction with skins. Some wells got water in alluvial gravel above the rock, others had to be carried into the rock until fissures were struck in strata so hard that progress was sometimes only possible by blasting. Wells in close proximity to each other gave different yields, and interference between distant wells was noticeable. Sometimes headings were driven to increase yields, and all wells benefited from rains, the water often rising to near the surface.

All the above facts fit in very well with the prevailing conditions and correspond with experience in the Sudan, Kenya, Tanganyika, South Africa, and other places where water is obtained from crystalline rocks. The conditions here are generally more favourable, due to the highly disturbed complex of rocks likely to cause differential decomposition and greater crevice volume. No convincing reason could be found for the congestion of wells in some valleys and their relative scarcity or absence in others, but it is doubtless due to the poorer

yields or greater depth to water in those with few wells. As elsewhere, there are people who claim the power of locating water, but no special significance was given to the views of these exponents of divining.

The more defined water-courses at lower levels are decidedly more favourable than the smaller valleys at higher levels, as drainage from a larger area reaches the lowest valleys, but thicker alluvial deposits would also be expected in major depressions. Largest yields of water would be expected from gravel and sands and the brecciated surface of the basement rock than from fissures in the rock itself where the water table is high enough to flood the alluvial deposits. There is, however, always the remote chance of striking an important fissure in the crystalline rocks in which case greatly increased outputs might be expected.

The striking of fissure water is always a "hit or miss" chance in such rocks, and usually there is no advantage in proceeding deeply into the rocks if nothing is found in the upper decomposed zones. A deeper fissure system might even drain water away by making contact with crevices leading to the scarp. Naturally we should like to see some holes drilled to about 200 ft. to explore the rocks at depth, but the expense would scarcely seem justified when shafts could be so cheaply sunk, especially with some skilled help and better tools. The policy advocated is to assist the people by grants to explore for water by shaft-sinking at points selected for trial by the authorities in the more important valleys but sufficiently removed from existing wells to avoid undue interference (say 600 ft.). Once a seepage zone was reached, work should be continued until the influx of water impedes progress or is such as to warrant the assumption that headings could be driven horizontally with hopes of success along fissure systems some 20 ft. below the upper limits of the seepage zone. The well-sinkers might be helped with tools and explosives, and in the event of success allowing the farmer to pay off the cost in instalments, whilst in case of failure the Government might meet the expense.

The land tenure arrangements appear to be unusually favourable to the cultivator on the plateau, for we were told that most peasants own the land, which is partitioned into small plots, and the cost of watering many plots from a common well is shared on some agreed plan: they pay in taxes 10 per cent of the produce, which, though high, is more reasonable than usual.

One well is said to water from one to three acres according to its state, and we were informed that the spring crop of wheat was watered five times with about 3" of water on each occasion. Many walled gardens were noticed near the villages, where apricot, figs and other fruits were grown, beside tomatoes and a few vegetables. Mr. Hartley thinks that a large variety of fruits, vegetables and produce could be grown here, and he planted some strawberries for trial.

The other great asset of Mukeris is sheep, herds of which were seen grazing on the millet stubble and on the hill-sides. They produce a silky wool capable of great improvement by crossing, and its utilization for the manufacture of rugs and blankets, constitutes a creditable peasant industry for the women.

A. BEEBY THOMPSON & PARTNERS.

APPENDIX

WESTERN PROTECTORATE

Total lift in feet	10	20	40	60
5,000 gals. hr. (about 5-acre inches a day)				
H.P. required	0.5	1.0	2.0	3.0
Cost - Engine and Pump			£90	£90
Fuel, gallons per day	1	2	2.7	4
10,000 gals. hr. (about 10-acre inches a day)				
H.P. required	1.0	2.0	4.0	6.0
Cost - Engine and Pump		£90	£90	£105
Fuel, gallons per day	2	3	5	8
15,000 gals. hr. (about 15-acre inches a day)				
H.P. required	1.5	3.0	6.0	9.0
Cost, Engine and Pump		£90	£105	£130
Fuel, gallons per day	2.5	4	8	12
20,000 gals. hr. (about 20-acre inches a day)				
H.P. required	2.0	4.0	8.0	12.0
Cost, Engine and Pump		£90	£130	£160
Fuel, gallons per day	3	5	10	15

Diesel Oil is likely to cost at distant points about 1/- per gallon or about 6d. per gallon in Aden.

Crops may take from 3" to 6" of water per month according to the produce grown and the season of the year.

The fuel consumed per acre irrigated would vary approximately as follows according to the size of plant:-

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Fuel required for 3 acre-inch watering:-

5,000 gals. hour plant		20,000 gals. hour plant	
10' lift	.6 gals.	10' lift	.45 gals.
60' "	2.4 "	60' "	2.25 "

Some additional small outlay for lubricating oil and stores would be necessary.

"CLIMAX" Windmills: Duties on basis of 12 miles per hour wind.

12 ft. Mill on 30 ft. tower:

Lift in feet	Low	25	50	100
Gallons per hour	3,000	1,450	570	400
Approx: acre-inches water per day	3.1	1.5	.59	.41

Cost £45 plus pump and tubing according to size and depth.

14ft. Mill on 30 ft. tower:

Lift in feet	Low	25	50	100
Gallons per hour	5,500	3,000	1,400	650
Approx: acre-inches water per day	5.7	3.1	1.4	.67

Cost £55 plus pump and tubing according to size and depth.
